



## In situ growth of layered carbon

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## In situ growth of layered carbon

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Nanostructured carbon materials are predicted to play a major role in future electronic applications. Cheaper and smaller components with improved or new functionality and lower power consumption are necessary, where conventional materials reach their limitations. Layered carbon materials, such as graphene or multilayer graphene, can be used for extremely compact devices with outstanding performance [1],[2]. A cheap way to synthesize such materials on a large scale is chemical vapor deposition (CVD) growth on catalysts like copper or nickel [3],[4]. However, the understanding and control of such growth processes are still in their infancy.

Here we present *in situ* transmission electron microscopy (TEM) experiments in a FEI Titan 80-300 Environmental TEM (ETEM) for studying the growth of layered carbon materials on Ni and Cu catalysts. The ETEM allows imaging with controlled gas environments around the sample up to a few mbar. In combination with a MEMS-based heating holder, growth of layered carbon materials is systematically studied at the atomic level using various carbon sources and growth temperature.

As an example, growth of few layer graphene from  $C_2H_2$  on a Ni catalyst is shown in Fig. 1-4. NiO particles in the size range up to a few hundred nm are reduced in the microscope under  $H_2$  at 500-600°C in order to form a catalytically active Ni surface. Introducing  $C_2H_2$  at about 650°C leads to growth of layered carbon (Fig. 1-4). By following the appearance of carbon layers, the growth rate dependence on various parameters can be determined directly from the ETEM observations.

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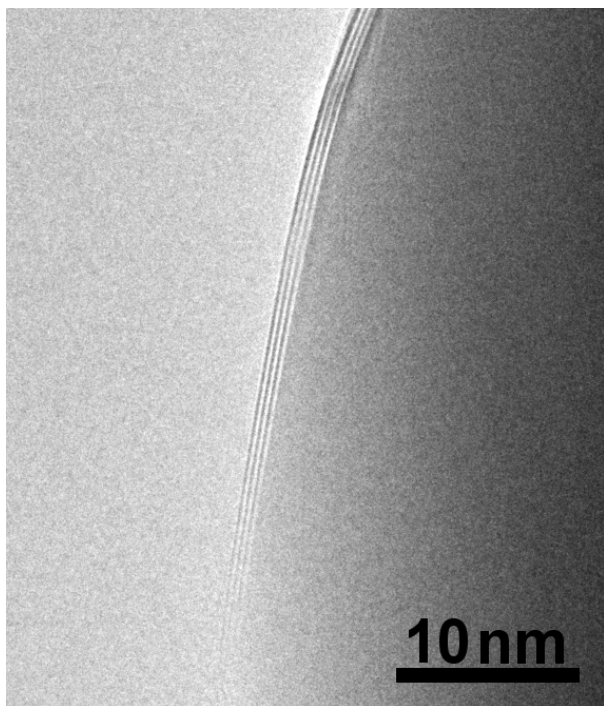


Fig. 1: Three layers grown shortly after introduction of  $C_2H_2$ .

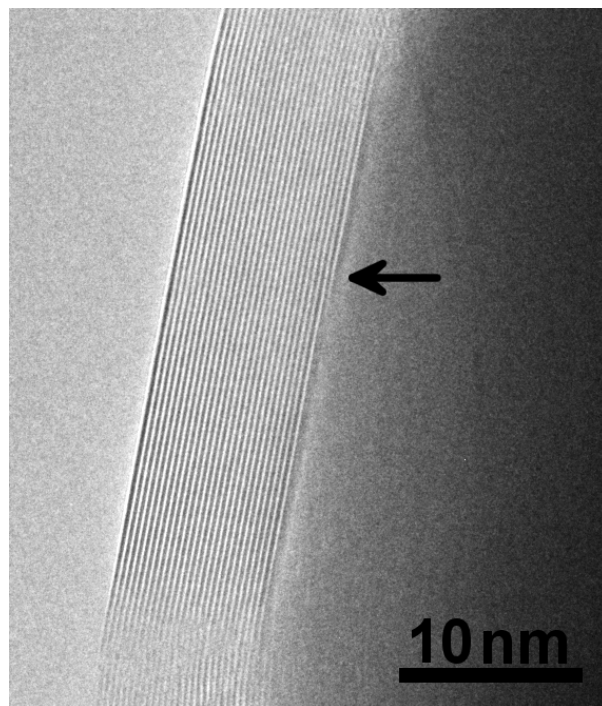


Fig. 2: Multiple layers grown 79.2s after Fig. 1; the arrow marks next growing layer close to the metal particle surface.

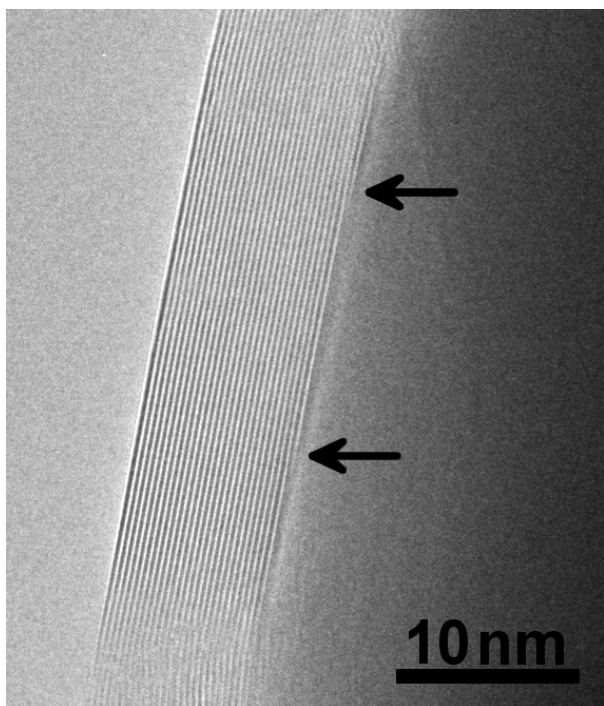


Fig. 3: Multiple layers grown 80s after Fig. 1; the arrows mark next growing layers close to the metal particle surface.

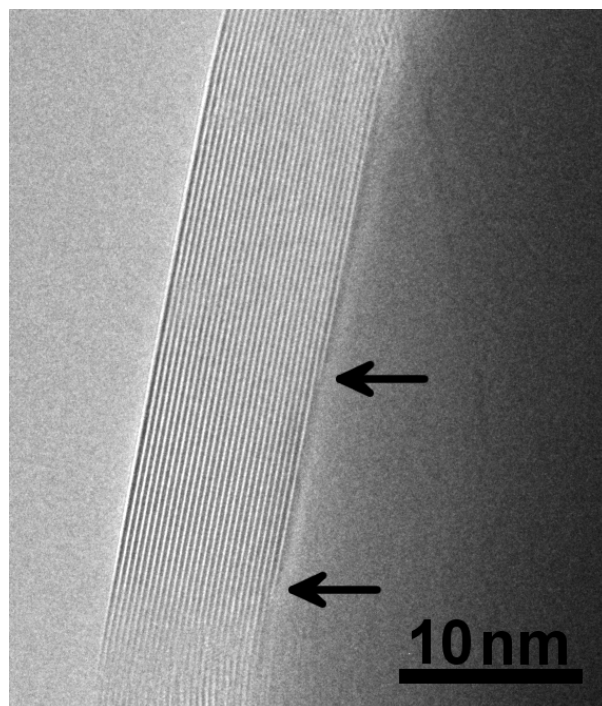


Fig. 4: Multiple layers grown 80.8s after Fig. 1; the arrows mark next growing layers close to the metal particle surface.